Coral cities of the deep

Species–habitat associations on the Mingulay Reef Complex

Lea-Anne Henry, Covadonga Orejas, Georgios Kazanidis, Laura Durán Suja, Ursula Witte and J. Murray Roberts

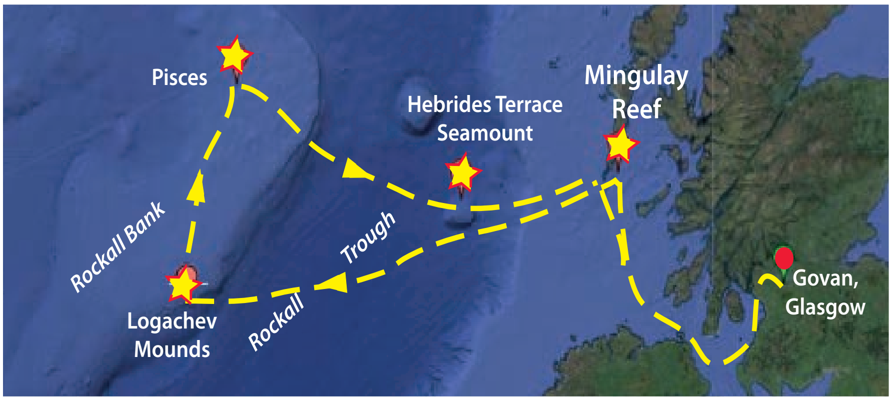
Mission to the Mingulay Reef

Global climate change is buffered in large part by Earth's oceans, which can capture and transport huge quantities of heat, salt, oxygen and carbon dioxide. The biome for which ecological impacts of this ocean buffering are least understood is the deep sea, and a race is underway to address this knowledge gap before impacts on deep ecosystems cannot be mitigated or managed.

With this challenge as its main focus, in May 2012 the Changing Oceans Expedition set sail from Govan, Scotland, on the RRV *James Cook* (cruise JC 073; Figure 1(a)) for a 5-week expedition to the outermost limits of the UK's 200 nautical mile exclusive economic zone, and into the high seas beyond national jurisdiction, to study some of Earth's most remote deep-sea ecosystems. The cross-disciplinary international team of researchers used the Irish Marine Institute's *Holland 1* Remotely Operated Vehicle (ROV) and a full suite of the latest oceanographic and acoustic *in situ* instrumentation to measure fine-scale hydrography and map deep-sea habitats. This approach delivered a full programme of research, allowing detailed investigations of the often complex relationships that deep-sea species have with their changing environments.

Part of the cruise mission was to re-visit the Mingulay Reef Complex (Figure 1(b)), a rare inshore shallow setting for cold-water coral reef ecosystems, which are typically found in the deep sea. Several researchers in the Changing Oceans science party, including Chief Scientist J. Murray Roberts, have been studying the complex since its discovery in 2003, and contributed the body of evidence needed for the Scottish government to designate it a Natura 2000 Marine Protected Area (MPA) under the EU *Habitats Directive*. The vulnerability of corals to disturbance by mobile fishing gear such as trawls and dredges, and the biological diversity associated with reef habitats (notably that supported by *Lophelia pertusa*; Figure 2), were core issues at the 2014 stakeholder consultations on fisheries management for the MPA. These discussions favoured a management option that would ban mobile gear throughout the complex, but allow creel pot fishing† between the reefs, thereby limiting disturbances to the reefs and reef fauna.

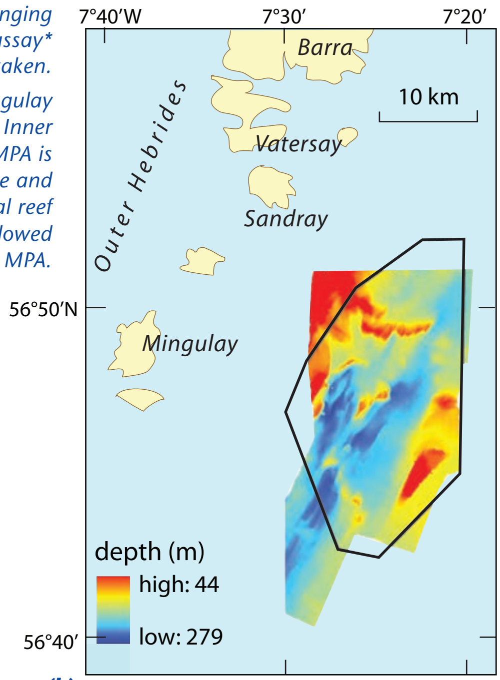
As work continues on the cruise data, new information about species' relationships with the reef habitats is emerging that strengthen the evidence



(a)

Figure 1 (a) *Track of the Changing Oceans cruise. Stars = sites where bioassay* experiments were undertaken.*

(b) *The location of the East Mingulay Marine Protected Area, between the Inner and Outer Hebrides. The extent of the MPA is indicated by the black box. The extensive and ecologically important cold-water coral reef ecosystem is the feature that allowed the area to be designated an MPA.*



(b)

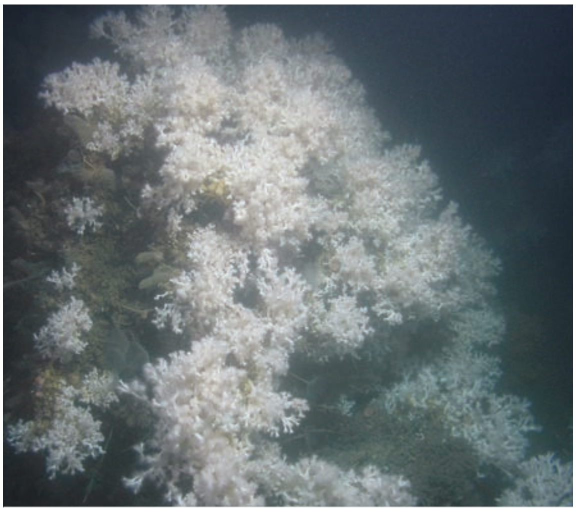


Figure 2 *Large colonies, ~ 2 m across, of the hard coral* Lophelia pertusa. Lophelia pertusa *reefs support thousands of other animal species.*

*A bioassay is an experiment to measure the effect of a substance on an organism (in this case, various concentrations of CO_2).

†Creel fishing – using baskets on the seabed – is an environmentally sustainable form of fishing with very little by-catch.

base for MPA designation. Species are often densely packed in these reefs, which makes observing their movements, and how they use the reefs, seem a little like visiting 'underwater cities'. In this article, we are focussing on three of these relationships that demonstrate not only how the different reef settings support an abundance of marine life including predators, but also how reef organisms contribute to the stability of the ecosystem and to biodiversity.

Sponge parks in the city

The reef complex is inhabited by a rich sponge fauna, with over a hundred species present including a previously undescribed species which has been named *Cliona caledoniae.* This lives by eroding into hard substrata.

The Changing Oceans Expedition conducted the first ever ROV video survey of sponge megafauna at the Mingulay Reef Complex, and there is much new knowledge to be gained from the video footage collected, particularly as it relates to how sponges promote biodiversity in deep-water ecosystems. Covadonga Orejas at the Spanish Institute of Oceanography, with Johanne Vad and Lea-Anne Henry at Heriot-Watt University, analysed the ROV dives and found many species-specific habitat preferences related to geology and hydrography. For example, the large habitat-forming sponge *Geodia barretti* occurred on flatter, south-facing habitats exposed to prevailing currents (blue areas in Figure 1(b)). In contrast, the sponge *Mycale lingua* occurred on hilly topographic highs (red areas in Figure 1(b)), whereas another sponge species, *Phakellia* sp., occurred on rocky habitats with little to no live coral cover. Therefore, where the various species of sponges occur is determined mostly by differences in environmental settings.

Associated with each kind of sponge are communities of other organisms, which exploit the characteristics of the sponge in question (e.g. using micro-currents created by the sponge drawing food into its body, or hiding from predators in small cavities in the sponge). JC 073 scientists have conducted a detailed investigation of the smaller macro-inhabitants such as hydrozoans and polychaetes, and those animals living on top of the massive habitat-forming yellow sponge *Spongosorites coralliophaga* (Figure 4). This aspect of research was carried out by Giorgios Kazanidis, Lea-Anne Henry, Ursula Witte and J. Murray Roberts at the University of Aberdeen and Heriot-Watt University. Analysis of these large yellow 'sponge parks' in the busy reef city revealed species-rich communities of animals (see Figure 4), which appeared to be using the surfaces of the sponges as platforms to feed from, and internal sponge cavities as places of refuge from predators – mainly polychates and crustaceans but also small fish.

Figure 3 *Sponge habitats at the Mingulay Reef Complex are home to hundreds of other species, including these ophiuroids (brittlestars).*

Figure 4 *One of the 'sponge parks' of bright yellow* Spongosorites coralliophaga *at the Mingulay Reef Complex. This large cluster of yellow sponges is nearly 2 m across.*

Tunicate builders

Research on cold-water coral reef biodiversity flowing from the JC 073 cruise continues to demonstrate how species other than the reef framework-forming corals can also enhance biodiversity. This is becoming evident in the case of the sponge fauna, but another new discovery at the Mingulay Reef Complex involves a rather inconspicuous sessile animal, the solitary tunicate *Polycarpa pomaria*. Laura Durán Suja at Heriot-Watt University discovered that besides providing habitat for a variety of epifaunal organisms such as bryozoans, hydroids and bivalves, *P. pomaria* densely colonises loose pieces of coral and binds these together into a very strong matrix, essentially stabilising coral patches over large areas (Figure 5). Like sponges, tunicates pump of water into themselves, creating micro-currents that attract other animals which can benefit from the incoming food. They also provide yet another surface for other animals to attach to and grow on. Our findings show how species living on the reef undertake

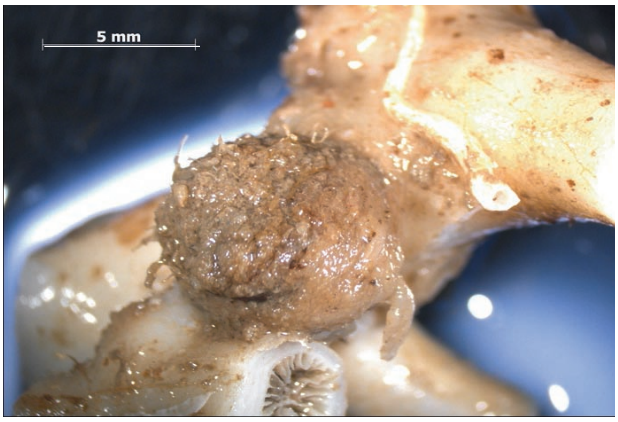


Figure 5 *The tunicate* Polycarpa pomaria *joins two pieces of dead coral reef framework (either side of the tunicate) together. This activity strengthens the reef, a previously undescribed role for tunicates in cold-water coral ecosystems.*

activities that make it more physically stable, which then attracts more species so increasing biodiversity, and so on. The ecosystem-engineering capacity of tunicates living on cold-water coral reefs has also been observed in the predatory polychaete worm *Eunice norvegica* and further demonstrates ecosystem feedback between reef biodiversity and long-term habitat stability.

New insights into predatory reef fish

Hundreds of invertebrate species have been found living in association with the Mingulay Reef Complex since the first programme of cold-water coral research began there in 2003, but until the Changing Oceans ROV video little attention was paid to the fish community, so little information was available on it. However the JC 073 scientific party undertook a novel investigation based on the ROV video. Among fish predators captured by the ROV video system were a few well known species including saithe *Pollachius virens* and the lesser spotted catshark *Scyliorhinus canicula*.

Unexpectedly, many egg cases of the deep-water blackmouth catshark *Galeus melastomus* were also collected. A more detailed investigation led by Lea-Anne Henry at Heriot-Watt University revealed that the egg cases had also been collected during previous missions to the complex. Habitat-mapping showed that spawning was occurring only in very specific environmental settings on the reef, and eggs were found in these sites year after year. Specifically, eggs were only deposited on live corals, in sea-floor valleys about 160 m deep, with moderate currents. This evidence suggests that *G. melastomus* may have environmental preferences for spawning in the complex and possibly exhibits high site-fidelity over several years.

Future research into the Mingulay Reef Complex

The JC 073 Changing Oceans Expedition will continue to provide a wealth of data with which to explore reef biodiversity, its effects on ecosystem stability, and the intricate and complex relationships between species and their habitats and global climate change. Beyond the three case studies outlined here, future research on biodiversity at the reef complex will include addressing major gaps in our knowledge of the fish fauna and the pelagic realm. To launch this new programme, a team of investigators including Lea-Anne Henry and J. Murray Roberts are collaborating with the Ocean Tracking Network (headquartered in Canada) to plan the first array of acoustic listening stations specifically designed to investigate movements and long-term habitat use by predators associated with a deep-water coral reef.

Figure 6 Holland 1's sampling arm reaches for shark egg cases among the reef framework of the Mingulay Reef Complex

Figure 7 A developing embryo of the deep-sea blackmouth catshark Galeus melastomus *found in an egg case deposited on corals in the reef complex. Still attached to its yolk sac, the shark is about 30 mm in length.*

Acknowledgements

The Changing Oceans Expedition was funded by the UK Ocean Acidification Research Programme (Natural Environment Research Council grant NE/H017305/1 to JMR).

Further Reading

Durán Suja, L., L.-A. Henry and J.M. Roberts (2015) The tunicate *Polycarpa pomaria*, a possible contributor to cold-water coral reef architecture. Poster, Deep-Sea Biology Symposium, Aveiro, Portugal, 30 August–5 September 2015.

Findlay, H., L. Wicks, F. Hopkins and M.P. Humphreys (2013) At sea with the UKOA: Investigating the effects of rising ocean acidity. *Ocean Challenge* **20***,* Summer, 5–8.

Henry, L.-A., J. Moreno Navas, S.J. Hennige, L.C. Wicks, J. Vad and J.M. Roberts (2013) Cold-water coral reef habitats benefit recreationally valuable sharks. *Biological Conservation* **161**, 67–70.

Kazanidis G, L.-A. Henry, J.M. Roberts and U.F.M. Witte (2015) Biodiversity of *Spongosorites coralliophaga* (Stephens, 1915) on coral rubble at two contrasting cold-water coral reef settings. *Coral Reefs* **35**, 193–208.

Roberts, J.M. and shipboard party (2013) *Changing Oceans Expedition 2012. RRS* James Cook *073 Cruise Report*.

Lea-Anne Henry is a Research Fellow at Heriot-Watt University. Her research seeks to understand the environmental drivers and ecological significance of biodiversity in the deep ocean. L.Henry@hw.ac.uk

Covadonga Orejas is a Scientific Investigator with the Instituto Español de Oceanografia in Spain. Her research covers the reproductive ecology, physiology and distribution of cold-water scleractinian and gorgonians in deep-sea habitats.

Georgios Kazanidis is a post-doctoral researcher at the University of Aberdeen working on the biology and ecology of sponges from cold-water coral reefs. His Ph.D studies were funded through a scholarship by the Marine Alliance for Science and Technology for Scotland (MASTS).

Laura Durán Suja is a Ph.D student at Heriot-Watt University. Her expertise is in the taxonomy and ecology of the meiofauna and macrofauna associated with cold-water coral ecosystems.

Ursula Witte is Professor of Biological Oceanography at the University of Aberdeen. She investigates the impact of climate change and anthropogenic perturbance on the diversity and function of benthic ecosystems.

Murray Roberts is Professor of Marine Biology and Director of the Centre for Marine Biodiversity and Biotechnology at Heriot-Watt University. His research focusses on the biology and ecology of cold-water coral ecosystems and the means by which vulnerable deep-sea ecosystems can be conserved.